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Introduction

The first edition of this bulletin closely followed the introduction of the first residual insecticide, DDT, which was hailed as a wonder chemical as it marked an immense step forward in the control of insect vectors of disease. Progress was rapid, other residual insecticides were produced, and eradication of malaria became a practical goal for some countries.

Now the easier victories against malaria have been won and many difficult areas remain. Insects have developed resistance to many insecticides, and it has been realised again that insecticides are only one of the weapons to be used in the fight against vector-borne diseases. And, as with all weapons, they need to be correctly used. This bulletin, again revised by Dr. G. Davidson from his immense experience of their use, aims to give a detailed practical guide to the choice and application of insecticides for the user. It considers methods for each insect group of medical importance and pays due attention to inseticide resistance problems. We trust it will continue to serve the needs of those who seek to control vectors and nuisance insects in the field.

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Insecticides

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Insecticides are now an accepted means of control of insect-borne disease throughout the world. Indeed the complete eradication of some diseases, in particular malaria, has been achieved in some parts by their use. However as a result of this widespread use, insects have now appeared which are resistant to them. Considerable research is continually going on on this problem of resistance with some solutions already being applied. These include the discovery of new insecticides to which these resistant insects are susceptible.

This booklet enumerates the common insecticides available at the present time and describes their use against the main insect disease vectors of the world, as well as other nuisance insects. The main principles which have emerged from a considerable volume of work on the resistance problem are outlined and remedies suggested where such a problem arises.

As is often the case where new and revolutionary methods are introduced there is a tendency for the indiscriminate use of these methods and the complete abandonment of previous ones. Such has been the case with insecticides and one seldom hears at the present time of any major attempt at permanent removal of insect breeding places as one did before insecticides were available. It must be remembered that effective control of insects by insecticides can only be achieved by their continuous use and this may in many circumstances be much more costly in the long run than the actual removal of insect breeding places. This has usually been found to be the case in urban areas where, though high initial costs may be involved in the removal of these breeding places, e.g. drainage of mosquito breeding sites and efficient sewage and rubbish disposal, such measures may lead to complete eradication of insect pests and thus eliminate the need of recurrent expenditure on insecticides.

In many rural areas, on the other hand, breeding places may be so numerous, scattered and inaccessible that their control by such permanent means is out of the question. In such circumstances insecticides are the answer and an undoubted boon.

Though insecticides in general, and those stable and persistent ones in particular, have come under attack in recent years from people concerned with their effect on non-target organisms including man himself, they must remain the principal weapon of attack against the insect pests of medical, agricultural and veterinary importance until such time as suitable alternative methods are discovered. Undoubtedly more attention will have to be paid to their methods of distribution, particularly in outdoor situations, so that they are more specifically directed against the pests, and to the search for less persistent, biodegradable compounds with a narrower range of activity with regard to insect species.

INSECTICIDES IN CURRENT USE

Insecticides used in the field of public health are usually contact insecticides and fall into two groups: the non-residual and the residual. Of the non-residuals the best known is pyrethrum which is the basis of ordinary ' flit '. Pyrethrum is a natural insecticidal mixture derived from pyrethrum flowers. The dried, powdered flowers can be used as such as a dusting powder but more usually a solvent extract is used diluted with kerosene as an atomised space spray. The insecticidal constituents of pyrethrum are unstable in light and air and so have virtually no residual effect.

Pyrethrum, being a very quick-acting insecticide, is of considerable value in the immediate alleviation of biting nuisance. It is usually used in the form of a space spray as a 0·1 per cent. solution of pyrethrins in kerosene and applied from a flit pump, a form of atomiser. At the rate of 1 fluid ounce per 3,000 cubic feet (29·6 ml. per 85 m^3) in a closed room kept closed for some ten minutes after application, such a spray will kill most insect pests which are in that room at the time of spraying. When the room is opened again, however, further insects entering will be unaffected and a further spraying will be necessary to kill them.

It must be emphasised that for the most efficient use of space sprays rooms must be closed when sprayed. It is realised that such conditions cannot usually be met in the tropics. Here efficient screening and the daily use of pyrethrum sprays in rooms closed as well as possible to kill the odd insects entering through opened doors or windows are recommended.

There is a tendency for some of the larger insects, e.g. blowflies, cockroaches, etc. to recover from an almost immediate knockdown by pyrethrum and nowadays a little residual insecticide, e.g. BHC, is added

to proprietary formulations to eliminate this tendency. Modern formulations also contain synergists, e.g. piperonyl butoxide, which increase the efficiency of the pyrethrum. An example of a domestic spray formulation is:—

	Percentage W/V
Pyrethrins	0·05
Piperonyl butoxide	0·4
*Lindane	0·1
Odourless petroleum distillate	99·45

Dispersion methods have also been improved by the development of aerosol containers, stout containers in which the insecticide is in solution in liquefied gases under pressure (propellants). Release of pressure causes the insecticide solution to be atomised in the most effective manner to ensure that the small particles are picked up by flying insects. These aerosol containers are usually operated for 3 seconds per 1,000 cubic feet (28 m^3) and deliver 1 gm. of formulation per second.

New synthetic pyrethroids, e.g. bioallethrin, bioresmethrin are now on the market which are even more efficient than the natural compounds. Examples of available formulations containing these new pyrethroids are:—

Ordinary flyspray:

	Percentage W/V
Pyrethrins	0·035
Bioresmethrin	0·01
Piperonyl butoxide	0·175
Odourless kerosene and propellants to ...	100

Aerosol:

	Percentage W/W
Bioallethrin	0·2
Bioresmethrin	0·02
Piperonyl butoxide	0·4
Odourless kerosene and propellants to ...	100

Non-residual aerosol sprays have been universally adopted by quarantine authorities throughout the world for the disinfestation of transport, particularly aircraft, to prevent the spread of disease and vectors from one country to another. The World Health Organisation

*Where organochlorine resistance is evident this may be replaced by 0·5 fenitrothion or 0·5 diazinon.

recommends the adoption of a standardised aerosol with the following composition for such disinfestation work:—

	Percentage by weight
Pyrethrum extract (25 % pyrethrins) ...	1·6
DDT technical	3·0
Xylene	7·5
Odourless petroleum distillate	2·9
Dichlorodifluoromethane	42·5
Trichlorofluoromethane	42·5

Two per cent. resmethrin or 2 per cent. bioresmethrin in the usual propellants are also recommended for this purpose.

Ground pyrethrum flowers or bioallethrin have been incorporated in slow-burning, joss-stick-type coils which produce an insecticidal smoke both toxic and repellent to insects. Such coils, burning for some nine hours, are widely used in houses in many parts of the tropics, particularly in the East.

An exciting new development is the discovery of stable pyrethroids with residual effects comparable with conventional residual insecticides. One whose code name is NRDC 143 has been given the appropriate common name of permethrin.

Residual contact insecticides are stable, organic chemicals which, when applied to a surface, remain toxic for some time, usually several months, to insects alighting on or walking over that surface. Particles of these insecticides, either in crystalline form or in oil solution, are picked up by the insect's feet and dissolve in the waxy outer layer of the cuticle; penetration into the insect follows, and so the nervous system is affected, leading to paralysis and eventual death. Their action is relatively slow; often several minutes contact is required and death may not occur for several hours. Thus a room treated with residual insecticide may not show dead insects inside it because the affected insects may leave the room and die elsewhere.

The residual contact insecticides most used in the control of insects of medical importance are the chlorinated hydrocarbons (organochlorines). However, cases of resistance to these insecticides are now quite common and other groups of chemicals especially organophosphates and carbamates are being investigated with regard to their toxicity both to man and to insects. Many are no more poisonous to man than DDT, e.g. malathion, temephos (= difenphos = abate), fenchlorphos (= ronnel), fenitrothion (= sumithion) and trichlorfon (= dipterex), all organophosphates and carbaryl (= sevin) and propoxur (= arprocarb), carbamates. Unfortunately none of these compounds has yet been shown to reach the standard of efficiency and persistence of the common organochlorines currently in use, particularly on mud surfaces. Also

cases of resistance to them are now appearing particularly in houseflies and in mosquitoes.

Of the many chlorinated hydrocarbon insecticides, only three have been used to any great extent in the control of insects of medical importance. These are, in order of their discovery:—

DDT (dichloro-diphenyl-trichloroethane) of which the para-para isomer is the most insecticidal.

Gamma-BHC (the gamma isomer of benzene hexachloride—trade names: ' Gammexane ' and ' Lindane ').

Dieldrin (hexachloro-epoxy-octahydro-dimethano-naphthalene) of which the endo-exo isomer is the most insecticidal.

DDT and dieldrin are both very stable and persistent, the former less toxic to most insects than the latter. Both are slower in action and less toxic than gamma-BHC which is, however, slightly volatile and so not as persistent as the other two. All three are to some extent irritating to some insects, e.g. mosquitoes and houseflies, causing them to leave a treated surface sooner than they would leave an untreated one. This irritant property is most marked in the case of DDT, which often causes the insects to leave a treated surface before they have picked up a lethal dose of the insecticide.

In many countries DDT remains the sole organochlorine allowed for pest control. BHC (or HCH as the World Health Organisation prefers to call it) and particularly dieldrin are now considered unsafe by many on toxicity grounds. In any case resistance to both compounds is commonplace. Some countries have even banned the use of DDT mainly because of its potential long-term pollutant effects on the environment.

Insecticide Formulations for the Residual Spraying of Buildings

All the residual insecticides are toxic to most insect pests in very small dosages and thus for their efficient application some dispersion medium is necessary. Most are insoluble in water and the use of solvents for their dispersion introduces additional costs. For this reason emulsions and water dispersible powders have been formulated, requiring only water for their dilution. Conflicting results from the use of these formulations were obtained in different parts of the world for some years; studies of the fates of these formulations on different types of surface have explained to some extent these conflicting results.

The facts emerging from these studies are:—

(1) The most efficient formulation is that which, when applied to a particular type of surface, leaves the insecticide on the surface in a form readily detachable or absorbed by the insect.

(2) When dissolved in oil, insecticides are most toxic to insects, since penetration through the insect cuticle is more rapid.

(3) The evaporation of the solvent from an oil film of insecticide usually causes crystallization in a form not easily detached by the insect.

(4) The speed of evaporation and consequent loss of toxicity depends on the solvent and the type of surface on which it is applied. Impurities in the insecticide or the addition of heavy oils may slow down evaporation and so prolong the toxicity. Evaporation from fibrous surfaces is in general slower than from smooth ones.

(5) The application of oil solutions to absorbent surfaces such as mud leads to a rapid loss of effect as the insecticide is lost from the surface. On fibrous surfaces such as paper and some woods this loss by absorption is not always permanent and the insecticide may return or ' bloom ' on to the surface in an easily detachable form.

(6) Emulsions (droplets of solution of insecticide held in suspension in water with the aid of an emulsifier) behave in general like solutions. Absorption on porous surfaces is, however, less rapid and, if heavy solvents are used in their preparation, the process of evaporation and crystallization is slower.

*(7) Water dispersible or wettable powders are the best formulations for use on absorbent surfaces; they are composed of particles of the insecticide ground with an inert filler, e.g. diatomite, talc, etc., with the addition of a wetting agent to ensure an even suspension when mixed in water. After application the water carrier is absorbed leaving the insecticide on the surface in a readily available form.

(8) The toxicity of solid insecticide particles depends on their size; the smaller the particle the more readily it is picked up by the insect. Particles of 10 to 20 microns have been found to be the most toxic.

*(9) The proportion and particle size of the inert filler in a wettable powder are important because of the possibility of masking of the insecticide particles. Some filler is essential in the grinding process involved in the manufacture of wettable powders as the pure insecticides are not easily ground alone (the heat generated in grinding may cause melting and clumping of the insecticide). Most wettable powders nowadays have at least 50 per cent. of filler but some with only 25 per cent. exist; obviously the less filler, the less masking.

(10) After the evaporation of the water on hard, non-absorbent surfaces, the wetting agent of these water dispersible powders, being of a sticky nature, tends to cause adherence of the insecticide particles to the surface so that they are not easily picked off by alighting insects.

*These statements do not necessarily apply in their entirety to liquid insecticides. Here wettable powders consist of filler particles impregnated with insecticides.

(11) On absorbent surfaces there is considerably less loss of insecticide from wettable powders than occurs with solutions and emulsions.

(12) On the most absorbent surfaces such as mud this loss from wettable powders may, however, be sufficient to cause a serious loss in efficiency of the non-volatile DDT and dieldrin. This has been clearly shown in laboratory tests but was not so marked in field trials. With the volatile gamma-BHC, on the other hand, no such loss in efficiency occurs for, through absorption may occur, this insecticide continues to kill by a fumigant action in its vapour phase. In fact, some degree of absorption is advantageous where this insecticide is used, because loss by volatilization is slower than on non-absorbent surfaces and so a more persistent but still lethal effect is obtained.

(13) Humidity has now been shown to affect the efficiency of insecticide deposits. Thus a sprayed surface giving only low kills in conditions of low humidity (' in the dry season ') may start to give and maintain high kills when the humidity increases (' in the wet season ').

All these facts may, at first sight, appear confusing, but the main practical deductions are that solutions and emulsions are only efficient when applied to relatively non-absorbent surfaces such as wood, metal, painted surfaces, etc. On these surfaces emulsions will usually produce a more persistent effect than solutions but the latter may be preferred where marking is undesirable. For absorbent surfaces such as the usual mud of dwellings in the tropics wettable powders are the only formulations which given an adequate available surface deposit. Very often both types of surface are present in one and the same building. The usual situation is one in which the roof is of non-absorbent material and the walls of absorbent material. Here, wettable powders are usually used throughout.

Residual Spraying

For the control of such insect pests as adult mosquitoes, houseflies, sandflies, etc., which rest at random on the walls and roofs inside buildings for at least part of the day or night, a uniform adequate dosage of residual contact insecticide on all these surfaces is required. To obtain such a uniform dosage a direct spray of liquid formulation is applied, sufficient to wet thoroughly the surface without running off and coarse enough to adhere to the surface. A very fine spray such as that produced by an atomizer, e.g. an ordinary flit-gun, is unsuitable as the tiny droplets produced tend to bounce off the surface being sprayed. The ideal nozzle size for residual spraying has been found to be $\frac{1}{32}$ in. to $\frac{3}{64}$ in. in diameter (0·8–1·2 mm.), the smaller for solutions and emulsions, the larger for wettable powders.

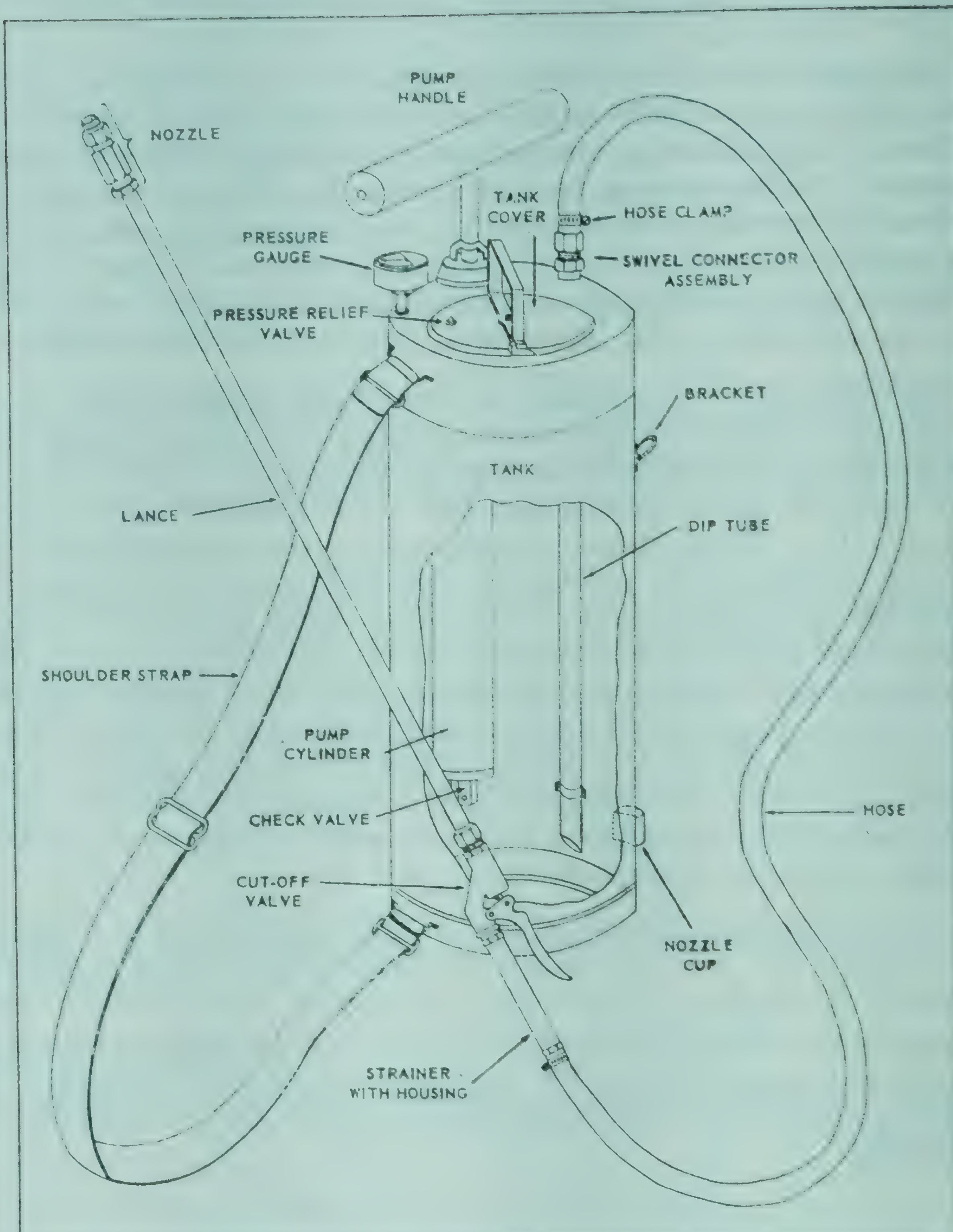
Undoubtedly the most efficient spray nozzle is that producing a fan spray in one plane and this is the one usually used for surface spraying. Distance between nozzle and surface has proved to be im-

portant in that it affects the proportion of spray actually adhering to the surface. The normal distance for maximum efficiency is 18 inches (45 cm.). This means that for the efficient spraying of high roofs and ceilings extension lances are necessary. Spraying is best carried out in vertical bands which are the width of the fan-spray.

The simplest of the spraying machines is the stirrup-pump type. Little maintenance of these machines is necessary and the operator can see if such formulations as emulsions and wettable powders are staying suspended in the water as spraying proceeds. Efficient manipulation requires the services of two operators, one for spraying and the other for pumping and, if necessary, stirring. In this last respect a useful addition to these machines is an attachment to the pump handle which moves up and down in the liquid while pumping is being carried out.

To eliminate the necessity for continuous pumping and so the necessity for a second operator, various types of pneumatic pumps have been designed, normally for carriage on the operator's back. These are filled with the liquid formulation and air is pumped in to a certain pressure. The World Health Organisation recommends an operating pressure of 40 pounds per square inch (2·8 kg/cm^2.) in conjunction with a fan-type spray nozzle with a spray angle of about 80° and an output of 0·2 U.S. or 0·17 Imperial gallons (757 ml.) per minute. Held at a distance of 18 inches (45 cm.) from the surface to be sprayed, such a nozzle and pressure should deposit a swathe of spray 30 inches (75 cm.) wide, of which the middle 14–16 inches (35–40 cm.) is effective. In practice, therefore, the marginal 7 or 8 inches (17·5–20 cm.) of one swathe should be overlapped by the margin of the next swathe to produce uniformity in deposit.

As the machine empties its two or three gallons (9 or 13·5 litres) of spray liquid the pressure almost invariable falls, and a consequent reduction in discharge rate ensues. A pressure control valve inserted between tank and spray lance can overcome such variation so long as the pressure in the tank exceeds that at which the control valve operates. The type of machine in common use to-day is shown in the accompanying illustration.



The usual type of machine employed for house spraying and the one recommended by WHO.

Pneumatic machines require a certain amount of simple maintenance, mostly involving the replacement of washers to ensure that there is no loss of pressure through leaks.

For large-scale work, various types of motor-driven compressors exist, but these need skilled maintenance. They are provided with several leads and spraying lances so that several sprayers can operate from the one machine, spraying several rooms or houses at one and the same time. They are usually mobile, either mounted on wheels or on a motor vehicle. Ease of access to buildings to be sprayed is essential where these machines are used.

With all spraying machines a careful check should be kept on the size of the nozzle apertures. Continuous use eventually causes an increase in aperture size especially when wettable powders are employed. This leads to over-application and wastage of insecticide. The problem of erosion has been overcome to some extent in recent years by the use of specially hardened steel, ceramics and plastics in the manufacture of nozzles.

As already stated, residual spraying entails the application of specific dosages of insecticide in a uniform manner. To calculate these quantities and dilutions of the formulations to give these specific dosages, three things must be known:—

(1) *The Pure Insecticide Content of the Formulation.*—By pure is meant the para-para isomer content of DDT formulations, the gamma-isomer content of BHC formulations, the endo-exo isomer content of dieldrin formulations and the pure organic phosphate or carbamate content of formulations of these insecticides. Specifications are usually given by manufacturers but if the formulations are being used in very large quantities it is advisable to have the insecticidal content checked by chemical analysis from time to time, as it may vary from consignment to consignment. Commercial DDT on which most of the formulations are based contains about 80 per cent. of the para-para isomer, crude BHC usually 13 per cent. of the gamma isomer (where manufactured as such, gamma-BHC is of 99 per cent. purity and called Lindane), and commercial dieldrin not less than 85 per cent. of the endo-exo isomer. Most solution and emulsion concentrates of all these insecticides contain about 20 per cent. w/v of the pure insecticide. Most DDT and dieldrin wettable powders contain 50 per cent. of the commercial insecticide, but 75 per cent. wettable powders are available. Modern BHC formulations are now based on Lindane and wettable powders containing 50 per cent. gamma-BHC are readily available.

Organic phosphates and carbamates are also formulated as emulsion concentrates and wettable powders and percentages of active ingredients vary from compound to compound. Many of the

phosphates are liquids and wettable powders are in fact impregnations of filler particles with insecticide.

The settling out in storage and transit of emulsions and wettable powders is not uncommon and leads to variations in insecticide content at differing depths in the containers. This can be checked by chemical analysis of samples from different levels and corrected by thorough mixing before use.

(2) *The Suspension Properties of Emulsions and Wettable Powders.*—No emulsion or wettable powder will stay in suspension in water indefinitely but obviously those settling out rapidly will make for unevenness in application. Crude tests by the addition of a small quantity of the formulation to the right amount of water in a glass tube are usually sufficient to indicate satisfactory dispersion or otherwise. Visible settling out should not occur for at least ten to fifteen minutes. The World Health Organisation has now laid down a detailed stringent test for the suspension properties of wettable powders and only those which meet the requirements of this test should be used. Because of the importance of efficient dispersion of emulsions and wettable powders, manufacturers' instructions regarding their dilution (e.g. creaming with a small quantity of water prior to final dilution) should be rigorously observed; dilution of these formulations should only be carried out immediately prior to spraying.

(3) *The Application Rate of the Machine.*—The application rates of spraying machines can be fairly accurately determined by spraying sheets of cloth of known area and weight with water, at a speed consistent with the thorough wetting to a point of run-off aimed at in ordinary surface-spraying, and recording the increase in weight after spraying. The usual rate lies between one-half and one Imperial gallon per 1,000 square feet (approximately 2·25–4·5 litres per 100 m^2). The World Health Organisation, in recommending a standard type of machine operating at a specified pressure combined with a specific nozzle size, advises the training of operators to cover 1,000 square feet (100 m^2) in the time taken for the machine to deliver one gallon (4·5 litres) of spray.

Usual application rates for the residual spraying of domestic premises in terms of grammes of active ingredient per square metre (multiply by 100 to obtain milligrammes per square foot) are:—

DDT—2
gamma-BHC—0·4
dieldrin—0·6
organophosphates—2
carbamates—2

The following table gives some examples of quantities and dilutions of some formulations needed to give such application rates, assuming

that the insecticide content of the formulation refers to the pure insecticidal isomer where such exists and that application is at the rate of one gallon per 1,000 square feet (4·5 litres per 100 m²):—

Insecticide	*Formulation*	*Insecticide content*	*Dilution required*
DDT ...	Wettable powder ...	50%	14 oz. per gallon of water (=90 gm. per litre)
DDT ...	Wettable powder ...	75%	9½ oz. per gallon of water (=60 gm. per litre)
DDT ...	Solution concentrate ...	20%	1 part to 3½ parts of kerosene
DDT ...	Emulsion concentrate	20%	1 part to 3½ parts of water
Malathion	Wettable powder ...	25%	28 oz. per gallon of water (=180 gm. per litre)

These dosages are those commonly recommended for the residual spraying of houses for the efficient control of most house-haunting insect pests, e.g. mosquitoes, houseflies, sandflies, bed-bugs, etc.

Organisation for Residual Spraying

A common mistake in the carrying-out of residual spraying campaigns is to entrust the actual spraying to the lowest-paid type of worker. It cannot be over-emphasised that the success of such campaigns depends on the application of an adequate, uniform dosage of insecticide on all possible resting places of the insect pests to be controlled. To achieve this requires considerable skill and the operators involved should be recognised and treated as skilled labour.

Of equal importance is the necessity for adequate and reliable supervision and in this connection a small manageable team is preferable to a larger and consequently more scattered one.

A simple unit, which can be multiplied according to the size of the control scheme is:—

- 1 supervisor whose function should also be to record the houses sprayed and those missed (for future spraying).
- 4 spray-operators, using pneumatic machines (if stirrup-pumps are employed the number of operators would need to be eight).
- 1 mixer, who is responsible for diluting and mixing the formulation to refill the machines.
- 1 driver, with a small vehicle for transporting equipment, water and personnel.

Before spraying is started it is advisable to explain in simple terms to the occupants of the houses the aim of the scheme, to warn them to leave their houses open on specified days and to remove their cooking and eating utensils, water, foodstuffs, small furniture, clothing, etc. Larger furniture such as beds and tables should be left inside the

houses and sprayed with the walls and roof; this furniture often serves as an additional resting-place for most house-haunting pests.

Under the most favourable conditions of house concentration and ease of access to them one machine operator should be able to spray 40 houses of usual tropical village size in one day. This may fall to as low as 10 per day in areas where houses are scattered however.

The time required to complete the spraying of an area must obviously be taken into account in organising a control scheme. If continuous control is required all the year round, the time taken should fall within the persistence time of the insecticide employed. If control is seasonal, spraying should be completed before the pest season starts and the toxic effects of the insecticide should persist until the end of the pest season.

Other Insecticide Formulations

In addition to the formulations used for the residual spraying of buildings, numerous other methods of dispersion of residual insecticides exist and some of these are now described.

(1) *Dusts.*—These are finely ground mixtures of insecticides and light, inert diluents such as china clay, talc, etc. DDT dusts usually contain 5 to 10 per cent. of the insecticide, BHC dusts 0·5 per cent. of the gamma isomer and malathion dust 1 per cent. of the insecticide. Dusts are commonly used in the control of agricultural pests and against cockroaches, fleas, fly maggots and lice, the precise location of which is usually known. Dusts are also useful as mosquito larvicides on breeding waters covered with considerable vegetation, where control by oil-films is impossible.

Various methods of distribution of dusts are employed ranging from the simplest by hand to the use of dustguns and aircraft.

(2) *Aerosols, Fogs, Vapours, Smokes and Fine Sprays.*—Aerosols are suspensions in the air of solid or liquid particles of insecticide, so fine (usually less than 50 microns) that they remain suspended for some considerable time. They are produced in a variety of ways from several kinds of machines:—

(i) *Atomizer*, in which a stream of air is made to impinge on a stream of insecticide solution, as in the ordinary flit-gun.

(ii) *Aerosol container*, in which the insecticide is dissolved in or mixed with liquefied gases under pressure. When the pressure is released, the carrier liquid boils off, dispersing a cloud of insecticide particles.

(iii) *Fogging-machines.*—Several types of larger machine exist for the production of aerosols. In the Todd Insecticidal Fog Applicator (T.I.F.A.) for example, an atomized spray is introduced into a hot or cold blast of air and further

fractionized. The hot blast of air is more commonly used and the aerosol termed thermal. In the Microsol machine a solution of insecticide is introduced between discs rotating at a very high speed (about 15,000 r.p.m.). The powerful centrifugal forces produced by these spinning discs is responsible for the distribution of the solution in very fine droplet form. The Swingfog machine operates on a pulse-jet system and the Micron Sprayer on a rapidly rotating atomiser and air-blast.

(iv) *Smoke generator*, in which the insecticide is mixed with a slow-burning chemical; when ignited it produces a smoke bearing fine particles of insecticide.

(v) *Aircraft.*—Two different principles are employed in the production of sprays from aircraft. The insecticide solution may be gravity- or pump-fed into a boom (beneath the aircraft wings) bearing nozzles at intervals along its length. The spray produced may not be very fine on emergence but is further broken up in the slipstream of the aircraft. Insecticide solution may also be distributed by introduction into the exhaust system of an aircraft, in a similar way to the production of a thermal aerosol from a fogging machine.

Aerosols are primarily used where rapid measures and good penetration are required and where residual effect is not of first importance. In fact surface deposits from aerosols, especially on vertical surfaces, are too small to produce much residual action. However, this concentration of fine particles suspended over long periods is very effective against flying insects; to stimulate flight pyrethrins are often included with residual insecticides dispersed in this form.

The larger aerosol machines have been very effectively used for the control of insect pests of stored products such as grain, tobacco, hides, etc. in warehouses, ships, trains, etc., and in the control of insects resting in dense vegetation, e.g. some mosquitoes, black-flies and tsetse flies. Also because of their rapid operation they have been found to be particularly effective where rapid control measures are considered more essential than the slower methods of applying residual deposits. Thus in epidemics of insect-borne diseases, such as fly-borne diseases and plague, the vectors can be rapidly reduced in numbers not only in dwellings but in outside breeding grounds.

Smokes have similar uses to liquid aerosols without the necessity of elaborate machinery for their production, but are not usually quite as effective. One reason is that a proportion of the insecticide is decomposed by the heat required for the production of the smoke.

The dispersion of insecticides by aircraft is expensive but often the only effective method of control of many widely distributed insect pests. The method has been extensively used in North America for the control

of outdoor-resting mosquitoes (mainly culicines) and their larvae and the larvae and adults of black-flies, which occur in enormous numbers over very large areas in that part of the world. Smaller-scale trials have also been made against tsetse-flies in Africa. Efficient aerial spraying can only be carried out under certain meteorological conditions and much depends on the particle size of the spray emitted and the density of vegetation to be penetrated.

Gaining considerable popularity nowadays is the dispersal of neat liquid insecticides by ultra-low-volume (ULV) dispersal methods which result in the dissemination of very small quantities over large areas. Malathion is often used in this way in the United States. It is either dispersed from the air using slow-flying aircraft or from ground equipment in the form of cold aerosol machinery mounted on slow-moving vehicles.

(3) *The Incorporation of Residual Insecticides in Whitewashes, Distempers, Paints and Resins.*—The mixing of insecticides with whitewashes and distempers has little or no advantage over the spraying of the insecticides on to such surfaces as the insecticide is diluted and masked by the whitewash or distemper. In addition, lime may possibly cause a slow decomposition of DDT and BHC. With oil-bound paints a great deal of the insecticide is lost in solution in the paint and is not available to contaminate the insect. With a high concentration of insecticide, i.e., more than sufficient to saturate the paint oils, ' blooming ' of crystals of insecticide may occur on the surface; they are highly toxic to alighting insects.

This principle of ' blooming ' from saturated solutions has been used with marked success in surface-coatings of urea-formaldehyde resins containing some 20 per cent. DDT. ' Blooming ' from these surfaces continues over long periods (as long as one year after application) and such surfaces withstand the usual methods of cleaning—in fact, rubbing the surface encourages ' blooming '. However, the expense of this formulation prohibits its widespread use.

(4) *Insecticidal Pellets or Granules.*—Pellets or granules of certain types of clay, impregnated with insecticide, which disintegrate slowly in water and release the insecticide, have been developed mainly as mosquito larvicides for use in shallow-water breeding places with much vegetation, where successful control by oil-films is impossible, e.g. rice fields. Some residual effect is claimed because of the slow release of insecticide. They can be distributed by hand or from the air and their heavier weight compared with dusts ensures penetration through dense vegetation to the water.

(5) *High-spreading Oil Larvicides.*—The control of mosquito larvae by the use of oil has long been practised; to produce a continuous film of oil toxic to larvae required some 20 to 25 gallons of oil per acre (900–1,125 litres per 4,047 m^2) in the past. The addition of spreading agents, e.g. certain resins, to oil, increases its spreading pressure considerably

and enables a marked reduction to be made in the quantities necessary to cover a given area completely. The addition of small quantities of the residual insecticides greatly increases the toxicity of such thin films. Thus 5 per cent. DDT in a high-spreading oil applied at only one quart per acre (1·14 litres per 4,047 m^2) will produce efficient larval control.

The dispersion of such small quantities over such large areas presents a problem far from solved as yet. Spraying from the air can only be the answer where large areas of water are involved and where economically feasible. The problem is partially solved by the use of a small oiler which squirts, at each operation of the plunger mechanism, 1 ml. of oil 15 to 20 feet (4·5 to 6 m), a sufficient quantity to cover 2 square yards (1·7 m^2) of surface.

Other larvicides dependent on continuous film production and being presently developed are lauryl alcohol, various mononuclear lipids—fatty substances which penetrate the tracheal system of both larvae and pupae—and Flit® MLO, a petroleum hydrocarbon. The latter is used at the rate of 1–5 gallons (4·5–22·5 litres) per acre (4,047 m^2), low volumes being sufficient for the control of anophelines but higher volumes being necessary for the more polluted culicine breeding places.

Precautions in the use of Insecticides

All the chlorinated hydrocarbons, organic phosphate and carbamate insecticides are poisonous to some extent to man. The following precautions are essential for persons habitually using dieldrin, organic phosphates, or carbamates. (Where DDT or BHC are used the special veil described in item (3) and the gloves described in item (7) are not considered necessary):—

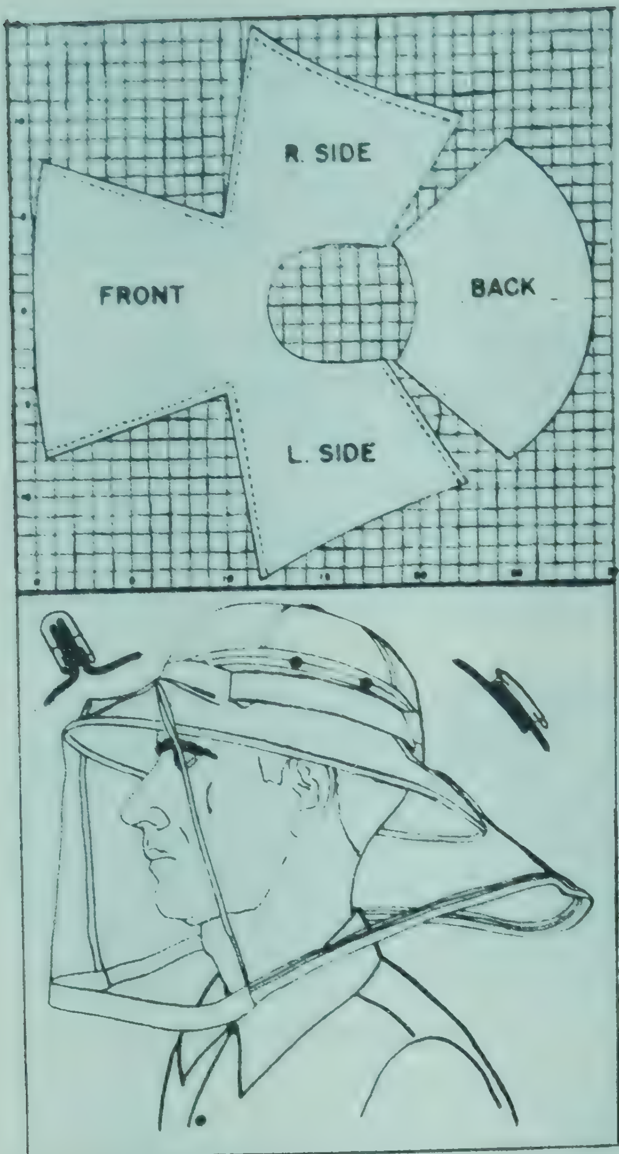
(1) Operators should be carefully instructed in handling, and should be informed that there is a risk in swallowing insecticide, or in excessive inhalation, or in contact of the material with the skin.

(2) Work should be carried out under adequate supervision.

(3) Operators should wear an effective protection to the head and face and it should be regularly cleaned. Such a head protection is illustrated and consists of a veil of plastic netting suspended from the brim of a light broad-brimmed hat or tropical helmet.

(4) Separate working clothes, which cover the entire body, should be used, removed at the end of each working day, and washed as frequently as possible. Ordinary cotton clothing is suitable.

(5) Operators should wash, using soap or detergent, at the end of each working spell, and whenever insecticide is spilled in quantity on the skin or clothes.



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(6) Operators should not smoke or eat whilst on duty, or at any time after it without having first washed their hands.

(7) Operators should wear impervious rubberised gauntlets.

(8) Operators should not work more than 4 to 5 hours a day on spraying.

(9) Equipment should be maintained in good condition, particularly so that it does not leak or spill over the operator. In addition the lowest spray pressures compatible with good spray pattern should be used thereby lessening the bounce of spray from the wall and operators should avoid as far as possible any spray drift.

(10) Insecticide should be handled with implements, scoops, spoons and mixing rods and not with the hands, and containers such as buckets should have handles, eliminating the tendency to soil the hands when handling them.

A very great risk occurs when handling strong oil solutions, as in mother-concentrates of emulsions, which should be handled through threaded taps, or by pumps arranged to prevent contact of the solution with the skin.

There is probably little real risk to the occupants of treated houses but as a safety measure all foodstuffs should be removed or carefully covered before a house is sprayed. There is some risk to domestic animals, especially with dieldrin, and casualties have occurred amongst cats, which can pick up a large dose by licking contaminated fur, and chickens which have pecked along the foot of treated walls.

The signs of acute poisoning by the chlorinated hydrocarbons include convulsions, accompanied by destruction of the liver tissue. Acute poisoning due to swallowing should be met by emetics, e.g. a tablespoon of salt in a glass of warm water. More chronic poisoning due to the continued intake of smaller quantities is heralded by nervous symptoms which include hyperexcitability, anxiety and tremors. In addition, there is a very marked loss of appetite which quickly leads to loss of weight. The nervous symptoms should be countered by the use of phenobarbitone (a maximum single dose of 3 grains (200 mg.) could be given if medical help were not immediately available and pending its arrival). On medical advice it may be necessary to increase this dosage and to maintain it over some considerable time. Animal experiments have indicated that large dosages of phenobarbitone over 2 weeks or more may be necessary to keep poisoned animals from showing hyperexcitability or convulsions and to enable them to eat and behave normally. The dosage is often in excess of that which would induce sleep or even anaesthesia in a normal animal. In human beings the dosage should be adjusted to the clinical signs.

Any person who is thought to have suffered toxic effects due to handling chlorinated hydrocarbon insecticides should be removed from risk of contact with the insecticide for a long period: dieldrin is known to persist in the body in toxic amounts for many months, and six months' freedom from further risk should be ensured.

Symptoms of poisoning by organo-phosphorus insecticides are similar in many respects to those of chlorinated hydrocarbon poisoning, but include also bronchial disturbances. In severe cases artificial respiration by mechanical means may be necessary before the administration intravenously of atropine followed by 2-pyridinium aldoxime methiodide (2-P.A.M.-iodide). It is strongly advised that supplies of atropine should be available in first-aid kits when organo-phosphorus or carbamate insecticides are being applied and that the spraying supervisor should be trained to administer atropine in emergencies. Medical help should be sought immediately poisoning is suspected and any administration of 2-P.A.M.-iodide left to the doctor. Organic phosphates inhibit one of the vital enzyme systems of the body, cholinesterase, and it is advised that people habitually handling these insecticides should have their blood cholinesterase activity checked periodically. Operators should be withdrawn from exposure if this activity decreases by 25% or more from a well-established pre-exposure value.

The insecticidal carbamates give rise to a more rapidly reversible cholinesterase-inhibitor complex. This makes it impossible to use estimates of cholinesterase activity *in vitro* as an accurate index of the activity of this enzyme in the tissues. In cases of poisoning by carbamates all the methods used for treating poisoning by organic phosphorus compounds are useful with one exception: 2-P.A.M.-iodide and other oximes are not recommended for routine use. Recovery from carbamate poisoning is usually quite rapid.

THE CONTROL OF SPECIFIC INSECT PESTS

General Considerations

The successful control of insects which merely act as mechanical carriers of disease involves their complete eradication or reduction to very small numbers; an example is the housefly, which can pick up the germs of such diseases as typhoid and dysentery on its body or ingest them. Usually, eradication can only be achieved by a combined attack on larvae and adults. With insects which act as true hosts to organisms of disease, i.e. in which the organism undergoes a cycle of development inside the insect, successful control entails the reduction of length of life of the insect vector to below the time it usually takes for it to become infective. This can be achieved by attack on the adult insect only and may not require drastic reductions in overall numbers. In the case of malaria, for instance, the parasite (*Plasmodium vivax* or *P. falciparum*—the extrinsic cycle of *P. malariae* is considerably longer) may take about two weeks to complete its development within the anopheline mosquito. The mortality required amongst an anopheline population to prevent any one individual living this length of time depends on:—

(*a*) the density of the anopheline vector population;
(*b*) the frequency of biting man;
(*c*) the natural mortality.

It has been estimated that a continuous mortality of about 50 per cent. would be commonly sufficient to intercept malaria transmission by species A of the *Anopheles gambiae* complex or *A. funestus* in tropical Africa, mosquitoes which occur in moderately large numbers, have a low natural mortality and feed usually every two days almost exclusively on man. In contrast, in India *A. culicifacies*, which may occur in very large numbers but feeds mainly on animals and has a fairly high natural mortality, would only require a continuous mortality of some 30 per cent. to intercept transmission. Thus a more efficient insecticide will be required in the former case than in the latter. DDT with its highly irritant nature may not in fact produce high enough mortalities to intercept transmission by the more efficient vectors and particularly those which do not spend all the time between egg-layings inside houses.

Measurement of the real mortality amongst insects exposed to residual insecticides involves the recovery, dead or alive, of all the insects coming into contact with them and the recording of delayed mortalities amongst those insects caught alive. This involves the fitting of window-traps to sprayed houses. The window-trap resembles a lobster-pot in that entrance, from the inside of the house, is possible but escape from it impossible. All other major sources of light are blocked off and the window trap is then the main attraction for insects wishing to leave. Mosquitoes entering the house through gaps in the eaves to feed on the occupant would rest on the walls or roof after feeding, some to die later

inside the house (these can be collected from the floor) and some to attempt escape from the house and to be caught in the window-traps. The latter are kept for some hours afterwards and the delayed mortality recorded. Thus the total mortality is represented by:—

$$\frac{\text{Total dead on floor} + \text{number dying later in window-trap}}{\text{Total dead on floor} + \text{total in window-trap}}$$

Huts treated with DDT never show a complete mortality even on the day after spraying but on most types of surface and against most anopheline species (in the absence of resistance) it will produce at least 50 per cent. mortality over a period of 6 months when applied at the rate of 2 gm./m^2. Thus most spray campaigns using DDT in areas of perennial malaria transmission are based on a twice-yearly spraying cycle. Where transmission is seasonal and the season lasts less than 6 months only one application per year will be necessary providing it is completed before the season starts.

BHC will usually produce a complete mortality for one or two months after its application but its effect will deteriorate rapidly in the third and fourth months particularly on non-absorbent surfaces and in hot climates. However longer persistences may occur on active absorbent muds where presumably absorption slows down volatilization.

Dieldrin having the stability of DDT without its marked irritant effect and the toxicity of BHC without its volatility can produce very long persistences. Unfortunately its human toxicity and the frequency and level of resistance it produces now limits its use.

Organophosphates and carbamates are by comparison with the organochlorines relatively unstable compounds especially in the presence of water and alkali. They do not therefore have such long persistences especially on mud surfaces. Many field measurements of mortalities produced by them have shown most of the kill to be produced by the deposits persisting on the non-absorbent parts of the building sprayed and some would advocate only spraying these surfaces in the interests of economy. Malathion, and in particular propoxur, are many times more expensive than DDT and if, as has been indicated by some field trials, spraying 3 and 4 times a year may be necessary, costs may be prohibitive. However, where resistance to the organochlorines is prevalent there may be little alternative to their use if disease control is required.

Some results.—In some parts of the world, mainly islands, it has been possible to eradicate some insect vectors completely, either by attack on only the larval stage or only the adult stage. *A. gambiae*, accidentally introduced into Brazil from Africa, was successfully eliminated by antilarval measures as were anophelines in the island of Cyprus. Successful eradication of *A. funestus* in Mauritius was achieved solely by anti-adult methods although coincidental elimination of the

other malaria vector, *A. gambiae*, failed. In the coastal region of British Guiana, *A. darlingi* was eliminated by the residual spraying of houses with DDT.

Eradication in limited continental areas surrounded by uncontrolled terrain and not protected therefrom by natural barriers such as desert, mountain ranges, etc., is a virtual impossibility as reinvasion from the uncontrolled area will occur. Nevertheless, the gradual cessation of control measures from the centre of the controlled area towards the periphery, leaving an outer barrier zone continuously treated, should be possible and lead to considerable saving in recurrent expenditure. Thus, in British Guiana, control was stopped in the coastal area and only possible courses of invasion from the hinterland controlled.

World eradication of a disease such as malaria as distinct from eradication of the insect vectors was until quite recently considered a distinct possibility. Now the idea has been abandoned for most of the larger areas of the tropics. Here the future will be dependence on a combination of control measures directed at specific localities, the reduction of disease in which will benefit the overall development of the country the most. These measures will undoubtedly include insecticides.

Resistance.—Resistance to all the chlorinated hydrocarbon insecticides is becoming more and more common among insects of medical importance and among houseflies and mosquitoes resistance to the organophosphorus compounds, carbamates and even to pyrethroids has been recorded in addition. This resistance is not acquired by insects after contact with insecticide but is inherent in some individuals of a population. It is these individuals and their progeny which survive the effect of contact with insecticide and replace the original mixed population. The speed with which resistance appears thus depends on the proportion of resistant individuals originally present and the pressure of selection. Dieldrin-resistant *A. gambiae* have been shown to be present in unsprayed areas of West Africa to the extent of more than 10 per cent. of the mosquitoes. Using an efficient insecticide like dieldrin which produces nearly 100 per cent. kills of susceptible mosquitoes, selection of a pure resistant population from such an area would occur within only a few generations of the mosquito population and within only a month or two after spraying.

Generally speaking, two types of resistance to the chlorinated hydrocarbons exist:—

(1) to DDT and allied products such as DDD and methoxychlor and

(2) to dieldrin and allied compounds, e.g. aldrin, chlordane, etc. and to gamma-BHC.

In some instances when one of these types of resistance has appeared it has been possible to continue controlling the insect species by a change of chlorinated hydrocarbon. For example, *A. sundaicus* in certain areas along the north coast of Java showed resistance to DDT,

some years after the wide-scale use of this insecticide in houses. A change of insecticide to dieldrin was successful and no resistance to dieldrin appeared in these areas, though it did so in areas on the south coast, and DDT was used in these areas.

In general, dieldrin-resistance is much more common and arises much more rapidly than does DDT-resistance. This is because dieldrin-resistance is of a much higher degree and is dominant or partially-dominant in its genetic expression, that is to say, that even the individual which is impure genetically is partially or sometimes fully resistant and can survive field-dosages of the insecticide. DDT-resistance, on the other hand, is usually of a low order and recessive in its genetic expression. Here, only the individual genetically pure for the resistance factor survives the field-dosage. Thus if the type of resistance in the insect population to be controlled is unknown at the outset it would seem preferable to use DDT rather than dieldrin or BHC. The development of resistance may then only be slow and sufficient mortality may be inflicted among the insect population to achieve the object of disease eradication. These arguments apply in particular to resistance in anopheline mosquitoes. In fact even if DDT-resistance is detected in anophelines it is not advisable to change the insecticide until it has definitely been proved by field observations that malaria transmission is on the increase.

Where resistance to both groups of chlorinated hydrocarbons occurs a change to one of the organophosphates or carbamates may be necessary. Resistance to one of the compounds in these groups does not necessarily mean cross-resistance to the members of the same group fortunately, though some evidence of cross-resistance between some carbamates and some organophosphates is evident. In other words, a wide choice of alternative insecticides still exists for most insect pests (houseflies may be an exception) though whether these can be afforded is another question.

To prove resistance entails a comparison of the susceptibility of the insect in question to a particular dosage of the insecticide before and after control measures have been adopted. The World Health Organisation has now produced several test kits for this determination of susceptibility, particularly for mosquitoes, bed-bugs, fleas, sandflies and lice. Alternative measures of control should not be resorted to until real proof is established and the possibility of failure of control due to other causes has been investigated. Other causes may be:—

(1) inadequate dosage of insecticide;

(2) poor formulation, e.g. large particle size;

(3) change in habits of insects, from indoor-resting to out-door resting, for example.

Ideally, the detection of resistant individuals before spraying programmes are commenced would determine the insecticide to be used.

Work on the mode of inheritance of resistance, much of which has been done in the Ross Institute laboratories, has shown the possibility of recognition of resistance in anopheline mosquitoes. In most species studied a single genetical factor is responsible for resistance and by the use of discriminating dosages of insecticides susceptible and resistant and sometimes hybrid mosquitoes can be recognised.

Anopheline Mosquitoes

The choice of anti-larval or anti-adult measures for the control of anopheline mosquitoes depends on local conditions. Where breeding places are not numerous and can be controlled by permanent measures such as drainage, canalization, filling-in, etc., these may prove more economical in the long run than the continuous use of insecticides. Where economics prohibit such measures, efficient larviciding may be cheaper than adult control but it must be remembered that those larvae which escape such control measures will produce adults which can live their normal length of life and so become infective. Where breeding places are so extensive and numerous that anti-larval measures are out of the question, as happens in many rural areas, anti-adult measures by means of residual insectides may be the only methods of control.

Fortunately most malaria vectors spend some part of their life inside houses and stay there sufficiently long to pick up a lethal dose of insecticide, if the houses are effectively treated. However, they do vary in the length of time they spend in houses and obviously the longer they do so the higher the mortality from insecticidal treatment is likely to be. Thus *A. funestus* in Africa tends to spend nearly all its time in houses, only leaving them to lay eggs. Species B of the *A. gambiae* complex, on the other hand, may only spend half its time in houses, the other half being spent resting elsewhere. The *Kerteszia* mosquitoes, *A. bellator* in Trinidad and *A. cruzi* in Brazil, are examples of mosquitoes which seldom rest in houses and so cannot be controlled by house-spraying. These mosquitoes breed in water, held in the axils of the leaves of bromeliad plants; control is exercised by the removal or treatment of such plants.

Larvicides.—Except at high and often uneconomical dosages, the residual contact insecticides have little residual effect when used as larvicides on or in water. This may be due to their dilution or to being washed away or to absorption by mud and vegetation. Thus mosquito larvicides have, in general, to be reapplied at intervals within the aquatic cycle of the species. This usually amounts to application once a week but the interval may be as little as five days in the hottest parts of the world.

The choice of formulation for larvicidal work depends on the type of breeding place. Oils ,which depend for their success on being able to spread into a continuous film, can only be used on relatively open water,

though of any depth. Where vegetation impedes the spread of oil, dusts, emulsions and pellets can be used. The two latter formulations are more efficient in shallow than in deep water as dilution is then not so great.

DDT has frequently proved its efficiency as a mosquito larvicide. The required dose is minute, about one-quarter of a pound of the active product to one acre (28 gm. to 1,000 m^2) of water surface, and the difficulties of treatment turn on spreading such a small quantity over such a large area. Two methods are used: the distribution of DDT in oils which have very high spreading properties, and the use of very dilute emulsions of an oil solution of DDT in conveniently large quantities. Preparations are therefore marketed in two types, a 5 per cent. solution of DDT in a " high spread oil " and an emulsion concentrate of DDT. The first is intended to be sprayed at the rate of about 2 to 4 pints per acre (0·28 to 0·56 litres to 1,000 m^2) of water surface; the second is intended to be diluted with water till the final strength of DDT is between 0·1 and 0·15 per cent. and then sprayed from a knapsack sprayer at the rate of 10 to 20 gallons to the acre (11 to 22 litres per 1,000 m^2).

Among the organophosphates malathion at 3 to 6 ozs. per acre (85 to 170 gm. per 4,047 m^2) has proved efficient as an anopheline lavicide, but becoming more popular because of its very low toxicity to man is abate. This can be applied as a dilute emulsion at the rate of 0·5 to 1·5 fluid ounces per acre (14–43 ml. to 4,047 m^2) or as sand-core granules containing 1 per cent. of the insecticide at 5–10 lb. per acre (2·27–4·45 kg. to 4,047 m^2) in shallow, clean water or 10–20 lb. per acre (4·54–8·90 kg. to 4,047 m^2) in tidal water of high inorganic matter content. Some considerable residual effect has been claimed for these treatments with abate.

Imagicides.—For most house-haunting anopheline mosquitoes residual spraying of the interior of houses at 200 mg. per sq. ft. (2 gm. m^2) of DDT will give efficient control for at least 6 months and at 40 mg. per sq. ft. (0·4 gm./m^2) of gamma-BHC for 3 to 6 months depending on the absorptive properties of the surfaces. The optimum dosage of the organophosphates malathion and fenitrothion and the carbamate propoxur appears to be 200 mg. per sq. ft. (2 gm./m^2) and persistences have varied from a few weeks to several months again depending on the prevalent surface sprayed.

As already pointed out, the residual insecticides are relatively slow in action and therefore treatment of houses with them may give only little relief from the bites of incoming mosquitoes before they succumb to these residuals. For relief from bites the frequent use of space sprays containing pyrethrins or the newer synthetic pyrethroids and DDT is preferred. It need hardly be said at this stage that little control of either insect pests or the diseases they carry will be achieved by the residual spraying of single or a few houses in amongst numerous untreated ones.

Insecticide resistance has now been established in some 44 species of anophelines, 28 of which are malaria carriers. All 44 species have shown dieldrin-resistance while 24 have shown resistance to DDT as well. Among those resistant to both DDT and the BHC-dieldrin group are some of the most important malaria vectors in the world, e.g. *A. gambiae* species A and B, *A. stephensi*, *A. culicifacies*, *A. sacharovi* and *A. albimanus*. To make things worse the last two of these species are now showing resistance to several organophosphates and to propoxur, *A. sacharovi* in Turkey and *A. albimanus* in Central America, as a result of the widespread use of these compounds for agricultural purposes.

Culicine Mosquitoes

The control of culicine mosquitoes, some of which are important vectors of disease, e.g. filariasis, yellow fever and various other virus diseases, is usually more difficult than the control of anophelines. Many of them, e.g. *Culex fatigans*, are less susceptible to insecticides, while some do not habitually rest in houses.

The most efficient method of control of *Aedes aegypti*, carrier of dengue, dengue haemorrhagic fever and of yellow fever, would still appear to be by the removal or treatment of breeding places which are usually small and in the immediate vicinity of houses. Abate sand granules form a most convenient method of treatment of water collections and seem safe even for use in drinking water. No increase in concentration of this insecticide could be detected in water treated at 3- or 6-week intervals nor were any toxic symptoms exhibited in a village population exposed to such treated water for 1½ years. The effective concentration is of the order of one part per million.

Aedes aegypti eradication programmes have in the past been based on the treatment of the interior and exterior of all possible breeding-sites and of the adjacent wall surfaces (i.e. the perifocal method) with conventional residual insecticides. In those territories in which *Ae. aegypti* normally rests in houses, house-spraying with residual insecticides has been successful to the point of elimination of the mosquito; this occurred in the coastal regions of the Guiana countries of South America where *Anopheles darlingi* was eradicated at the same time.

In most other instances of culicine nuisance, anti-larval measures of control are the most effective. Many species which habitually bite man breed in well-defined waters quite near to habitations. Control by removal or treatment of these breeding places is often relatively simple; the difficulty lies in locating all of them. In general, insecticidal emulsions, suspensions and pellets are better as larvicides than oil-solutions, especially where there is a large amount of organic matter in the water as there often is in culicine breeding places; this prevents the spread of oil. Higher dosages than those used for the control of

anopheline larvae are usually required and allowance must be made for effects of dilution where water is deep. Dursban (chlorpyrifos) is a particularly good larvicide for use on water of high organic content.

The control of widespread culicine breeding is a much more difficult problem. Here fogs, dusts and ultra low volume (ULV) applications come into their own. In the United States the control of salt-marsh mosquitoes *Culex tarsalis*, the chief vector of western equine encephalitis, is usually effected by such means using malathion, naled (dibrom), abate, dursban, propoxur and now the synthetic pyrethroids. Dissemination may be from the air or from ground equipment (malathion is the only insecticide allowed to be dispersed from the ground). Application rates of malathion and abate used are 0·2–0·5 and 0·05–0·1 lb. per acre respectively (91–227 gm. and 23–45 gm. per 4,047 m²). Multi-resistances are now common in all the species involved.

The control of *Mansonia* mosquitoes, the main vectors of rural filariasis in Ceylon, has been successfully achieved by the use of the sodium salt of methyl-chlorophenoxyacetic acid to kill the plant *Pistia stratiotes* to which the larvae of these mosquitoes attach themselves. 2 oz. (57 gm.) of this herbicide per gallon (4·5 litres) of water sprayed over the plants at the rate of 36 gallons (162 litres) per acre (4,047 m²) kills young plants in 5–10 days and old plants within about 14 days.

Resistance to all the chlorinated hydrocarbons is widespread in *Culex fatigans* and even in its susceptible state this species in the adult form shows a high natural tolerance to them. The larvae of susceptible *C. fatigans* are quite susceptible, however, particularly to DDT. Organochlorine resistance is now widespread in *Ae. aegypti* and cases of organophosphate resistance are beginning to occur.

Houseflies

Aerosols or 'space sprays' are widely used in households for destruction of houseflies and other flying insects. While this method cannot deal completely with a serious fly nuisance it is a reliable way of ensuring the destruction of small numbers of intruders into larders, kitchens, etc. Some of the more modern aerosol sprays have already been described.

In using residual insecticides against houseflies attention is usually directed against those areas where these insects tend to congregate, rather than the complete spraying of the insides of houses. Such places as doors, windows, sills, some of the outside surfaces of houses, kitchens, porches, latrines, animal shelters and fences should receive special attention where the control of adult flies is concerned and, where larval control is aimed at, refuse dumps and accumulates of animal excrement and their vicinity. The spraying of refuse dumps, especially where these are large, will not always kill fly larvae but will

kill flies attempting to lay their eggs there and also new adults as they emerge. It must be emphasised that no insecticidal treatment can replace efficient methods of rubbish and excrement disposal.

As residual sprays the chlorinated hydrocarbon insecticides can be used at the rates advocated for mosquito control and will suffice to control both larval and adult houseflies providing resistance to the insecticides is absent. Unfortunately it seems almost inevitable that resistance will develop, and rapidly too, and the replacement of DDT by dieldrin or BHC will soon result in resistance to all the chlorinated hydrocarbons.

Nowadays emphasis is on the use of organophosphates with diazinon, dimethoate, fenthion, tetrachlorvinphos (Gardona), malathion, naled and ronnel all being recommended but with some restrictions on the use of some of them in dairies, milk rooms, poultry houses and food-processing plants (see 17th Report of World Health Organisation Expert Committee on Insecticides. *Tech. Rpt.* Series No. 443, 1970).

It has been found helpful to add attractants, e.g. sugar, molasses, to these insecticides at the rate of 2·5 parts attractant to one part of toxicant. As an example, malathion-sugar emulsions or suspensions at 2 gm./m^2 of malathion and 5 gm./m^2 of sugar give good control for 1–5 weeks and diazinon and sugar at 1 gm. diazinon and 2·5 gm. sugar/m^2 give good control for 4 or 5 weeks. Spot treatment of areas where flies are known to congregate is favoured rather than the wholesale spraying of buildings.

A recent innovation is the use of cords or strips impregnated with insecticide and hung in buildings. 5 mm. (3/16 in.) cords dipped in 25 per cent. diazinon-xylene solution and installed at the rate of 30 feet (10 m.) of cord per 100 sq. ft. (10 m^2) of floor area have been found to be effective for 5–6 months in dairy barns in the U.S.A. Great care is needed in the handling and preparation of these cords which should be marked or coloured to show what they are and to prevent them being used for other purposes. In Scandinavia strips of gauze impregnated with parathion and festooned from the ceilings of buildings are favoured. Parathion however, is the most poisonous to man of all the organophosphorus insecticides and so has to be very carefully handled.

Organic phosphates, e.g. malathion, trichlorfon, ronnel, diazinon, naled, dimethoate and dichlorvos, have also been incorporated in liquid and dry baits for spot treatments against flies. 0·1 to 0·2 per cent. toxicant and 10 per cent. attractant applied by watering can at 0·8 to 2·5 gallons per 1,000 sq. feet (3·6 to 11·25 litres/100 m^2) of floor area has been found efficient. In a dry state 1 to 2 per cent. toxicant added to granulated sugar and scattered at the rate of 2 to 4 oz. per 1,000 sq. feet (57–114 gm./100 m^2) has been used. Two treatments per week by these methods for 2 weeks was found to give good control for 12 weeks.

Diazinon appears to be one of the most potent organic phosphates for use as a larvicide. 0·5 to 1 gm./m² applied in 6 to 12 gallons (26 to 54 litres) of water to every 1,000 sq. feet (100 m²) is efficient for 10 to 14 days. Ronnel is also particularly effective against houseflies, and has a low mammalian toxicity. In the United States it has been found to be effective as a residual spray for 4–5 weeks at 100 mg./sq. ft. (1 gm./m²) and at double this rate for 8–9 weeks. It has also been used successfully as a cord-impregnant.

Other suggested uses of insecticides for housefly control are to be found in Ross Institute Bulletin No. 5.

Resistance to the organic phosphates in houseflies is already of common occurrence. Cross-resistance patterns within this group of insecticides are not yet clearly defined. Malathion resistance apparently imparts resistance to only a few other organo-phosphorus compounds while diazinon-resistance imparts a wider cross-resistance. Diazinon and trichlorfon seem at present to be suitable alternatives where malathion resistance is present. Some evidence exists of cross-resistance between organic phosphates and carbamates.

Paradichlorobenzene is said to give satisfactory control of fly-breeding for 1–2 weeks if added to dust-bins at the rate of 60 gm. or 2 oz. per bin. This is a simple means of control suitable for the individual householder.

Sand-flies

The spraying of houses with residual insecticides at the dosages given for anopheline control will control the adults of *Phlebotomus* species, the vectors of sand-fly fever and kala-azar. The breeding places of these insects are usually very difficult to locate and are said to occur mainly in the rubble of old walls or similar debris. No case of resistance in these insects is yet known.

Fleas

Concentration of insecticide treatment on the usual haunts of these insects rather than complete spraying of houses is more efficient. In the case of the human flea, *Pulex irritans*, this involves the application of insecticide dusts, e.g. 10 per cent. DDT or 0·5 per cent. gamma-BHC, to clothing, bedding, carpets and house-floors. Rat fleas, e.g. *Xenopsylla choepis*, the principal vector of plague, can be similarly controlled by concentration on rat burrows and runways. Higher dosages, e.g. 50 per cent. DDT powder or 3 per cent. gamma-BHC powder, are reputed to kill the rats as well as the fleas. The rats are poisoned when they lick insecticide off their feet. Fleas of domestic pets can be controlled by the use of dilute dusts, e.g. 5 per cent. DDT, 0·5 per cent. gamma-BHC, although care must be taken not to apply in too large quantities for fear of poisoning animals, especially cats, which are in the habit of licking

themselves. Malathion dusts (4–5 per cent.) are also effective against dog and cat fleas and can be safely applied to the host animals in moderate quantity. Other insecticides that have been used with success on pets for flea control either as dusts, dips, washes or sprays are carbaryl (a carbamate), coumaphos (an organophosphate), pyrethrum and rotenone. All should be applied to the animals' sleeping quarters as well as to the animals themselves. A method suitable for some pets is the wearing of collars made of plastic impregnated with the volatile organophosphate dichlorvos. The vapour given off is reputed to kill the fleas over a considerable period of time. Silica aerogels (see section on cockroaches) should be particularly useful for the control of fleas of domestic animals and without any toxicity risks. Several cases of resistance to the chlorinated hydrocarbon insecticides, particularly DDT, have been recorded in fleas and malathion resistance has been found in *X. cheopis* in India and Vietnam.

Bedbugs

There are two species associated with man. *Cimex hemipterus* is strictly tropical, while *C. lectularius* is world-wide in its distribution. Though not definitely associated with the transmission of disease, these insects are particularly irritating in their bites and obnoxious in their smell. They are so much disliked the world over that when house-spraying was instituted as a malaria control measure it was more welcomed in some parts as a means of bed-bug control than for what it was primarily intended and when the bed-bugs became resistant to the insecticides it became more and more difficult for spraymen to gain access to the houses.

Ordinary residual house-spraying combined with special attention to crevices in walls, floors and furniture and to beds and bedding (and perhaps aided by the flushing effect of added pyrethrins) will effectually control bed-bugs for long periods. Unfortunately, resistance to the chlorinated hydrocarbons is now widespread. Malathion (0·5 to 1 per cent. spray) is usually adopted as a substitute in such circumstances but cases of resistance to malathion and other organophosphates are now known. Suggested alternative sprays are ronnel (1 per cent.), trichlorfon (0·1 per cent.), propoxur (1 per cent.) and dichlorvos (0·5 per cent.). Care must be taken in applying some of these chemicals. They must be applied sparingly and only to the bedding of adults and not to that of infants. Retreatments should not be made at less than two-week intervals. Synergized pyrethrin sprays (0·2 per cent. pyrethrins) are also effective though two or more applications may be necessary at intervals of 2 to 6 weeks.

Reduviid Bugs

Variously known as cone-nose bugs, assassin bugs, barbeiros, kissing bugs or china bugs, several species are carriers of Chagas'

disease in Mexico and Central and South America. The main genera concerned in the transmission of the disease to man are *Triatoma*, *Panstrongylus* and *Rhodnius*. Numerous animal species such as armadillos, opossums, domestic and wild rodents, birds, dogs and squirrels act as reservoirs of the disease agents, various trypanosome species.

Like bed bugs, these bugs spend most of their time in cracks and crevices in human habitations though in addition they are to be found in animal haunts and birds' nests. As for bed-bugs, house-spraying with residual insecticides with special attention to crevices is the usual control method adopted. Treatment of peridomestic infestations in chicken houses, pigeon lofts and piggeries is often carried out at the same time. The usual insecticides have been dieldrin at 1 gm./m^2 or gamma-BHC at 0·5 gm./m^2 but resistance to both is known in *Triatoma maculata* and *Rhodnius prolixus* in Venezuela. DDT is said to be ineffective and various organophosphates are under consideration as alternatives.

Ticks

DDT is not very effective against *Ornithodorus moubata*, the vector of relapsing fever in Africa and India. In East Africa effective control has been achieved by two applications of heavy dosages of crude BHC in powder form (approximately 150 mg. of the gamma isomer per square foot or 1·5 gm./m^2) to the floors of native dwellings. The second application, three weeks after the first, killed off those ticks which survived the first treatment in the egg-stage. Such a dosage is exceedingly high and more recent trials have indicated that lindane wettable powder in suspension in water, applied at 10 to 15 mg. of the gamma isomer per square foot (0·1 to 0·15 gm./m^2) will achieve control if repeated at monthly intervals. There is no evidence of resistance of *O. moubata* to BHC.

Other ticks are vectors of various rickettsial, bacterial and virus diseases throughout the world. These include Colorado tick fever, American spotted fever, tick-borne encephalitis, 'Kyasanur forest' disease, haemorrhagic fevers and tularaemia. Animal ticks such as *Dermacentor variabilis* and *Rhipicephalus sanguineus* both of which occur on dogs and are commonly found resting on vegetation, can be controlled by area applications of the chlorinated hydrocarbons to vegetation, e.g. DDT at 2 lb. (907 gm.) toxicant per acre (4,047 m^2) or gamma-BHC at 0·5 lb. per acre (227 gm./4,047 m^2). Suspensions, emulsions or dusts can be used. Treatment with these chemicals usually prevents reinfestation for 30 days or more. Where resistance to organochlorines occurs gardona at 1 lb. per acre (454 gm./4,047 m^2) or carbaryl at 2 lb. per acre (907 gm./4,047 m^2) may be used.

Treatment of the animals themselves can be by washes, sprays, dips or dusts. Washes or sprays containing 1 per cent. DDT, 0·5 per

cent. malathion, 1 per cent. coumaphos or 0·05 per cent. lindane or rotenone are suitable. Dips should be one-half of these concentrations. Dusts should contain 5–10 per cent. DDT, 1 per cent. lindane, 4 or 5 per cent. malathion, 3 to 5 per cent. rotenone, 5 per cent. carbaryl, 0·5 per cent. coumaphos or 1 per cent. trichlorfon.

Where animal ticks invade houses spot treatments of baseboards, floor and wall cracks, and the sleeping area of the animal with formulations containing 1 per cent. propoxur, 0·5 per cent. dioxathion, 2 per cent. ronnel or 0·5 per cent. lindane have all been used successfully. 0·5 per cent. diazinon in the form of an emulsion or in solution, 1–3 per cent. sprays of malathion or fenthion or 2 per cent. suspension of carbaryl have similarly been used to treat indoor infestations as well as fences, shrubs, yards and the exteriors of buildings.

Against the forest and scrub-dwelling ticks *Ixodes* and *Hyalomma plumbeum* ground and aircraft dusting and fogging methods have been used with the chlorinated hydrocarbon insecticides.

Lice

Three different kinds parasitise man—body and head lice and crab lice. The last two stay on the body continuously. The first is to be found in the clothing except when feeding.

The body louse (*Pediculus humanus corporis*) is the carrier of typhus and relapsing fever both of which have been responsible for serious epidemics in the past. 10 per cent. DDT dust (usually talc) is the customary remedy for this pest. It causes cessation of feeding in three hours, complete knockdown in six hours and complete kill in twenty hours. One application to clothing will give thorough protection for three weeks; although eggs are unaffected, all will have hatched in this period. The dust can be effectively applied from a plunger-type dust-gun with a long nozzle for insertion beneath clothes without the necessity for undressing. 1½ to 2 ozs. (43 to 57 gm.) is required per person. Alternatively, sifter-top cans can be issued for individual use. A 1 per cent. lindane powder may be used where DDT resistance is present, though here a second application within 7–10 days of the first may be necessary. Where resistance to both DDT and lindane has arisen 1 per cent. malathion, 2 per cent. abate, 5 per cent. carbaryl, 1 per cent. propoxur or 5 per cent. mobam (another carbamate) dusts can be used. Resistance to malathion has been found in Burundi.

The impregnation of clothing with DDT formed an effective way of combating lousiness during World War II. This clothing retained its insecticidal effect after several launderings.

Head louse (*Pediculus humanus capitis*).—For control of head lice liquid formulae are preferred to dusts since they are not noticeable in the hair. One well-tried formula (the N.B.I.N. formula) is composed of 6 per cent. DDT, 68 per cent. benzyl benzoate (which is also sarcopti-

cidal), 14 per cent. Tween 80 as emulsifier and 12 per cent. benzocaine, which eliminates irritation and acts as an ovicide. Another effective emulsion concentrate is 1 per cent. lindane in alcohol together with an emulsifier. These concentrates are diluted 1 part concentrate to 5 parts water before application. Treated persons should not bathe or wash their hair for at least 24 hours.

Crab louse (*Phthirius pubis*).—A single application of the N.B.I.N. formula will effectively control crab lice; two dustings, a week apart, with 10 per cent. DDT dust or 1 per cent. lindane powder may also be used.

Marked resistance to DDT among lice was first noticed among troops serving in Korea. At the present time DDT-resistance is widespread and cases of BHC-resistance are also known. Experiments are now being made on pyrethrins and allethrin (a synthetic compound similar to pyrethrins), with synergists, to replace the chlorinated hydrocarbons. One formulation that has been effective in practical use contains 0·2 per cent. of pyrethrins, 2 per cent. of sulfoxide (as a synergist), 2 per cent. of 2, 4-dinitroanisole (as an ovicide), 0·1 per cent. of Phenol S (as an antioxidant), and 3 per cent. of a conditioner in a suitable dust carrier. This powder has a shorter residual action than DDT and treatments should be repeated weekly until the infestation is controlled.

Cockroaches

Not usually recognised as important carriers of human disease, cockroaches, with their haphazard association between dirt, including human and animal excrement, and human food, undoubtedly contribute to the mechanical transmission of enteric and other illnesses. The three main species, the German (*Blattella germanica*), Oriental (*Blatta orientalis*) and American (*Periplaneta americana*) cockroaches often present noticeable pest problems in the warmer parts of premises in temperate climates where they are usually associated with kitchens and central heating installations. They are more efficiently controlled by treatment of their 'runs' than by treatment of the whole building. Chemical control can be achieved by applying organochlorines, organophosphates or carbamates as residual sprays or as dusts in affected areas. Among the organochlorines 0·5 per cent. gamma-BHC or 5 per cent. chlordane dusts have been used as well as a fine dust made up of 20 parts of ground pyrethrum flowers, 10 parts of technical DDT and 70 parts of chalk applied at weekly intervals. Effective control has also been achieved by the application of urea-formaldehyde resins containing dissolved organochlorines, e.g. DDT. These give very prolonged protection (one year or more) and are particularly suitable for hospitals or ships' galleys and food storage rooms.

Organophosphates used with success have been 2 per cent. diazinon and 5 per cent. malathion dusts and 0·5–1 per cent. diazinon,

0·5 per cent. dursban and dichlorvos and 3 per cent. fenthion sprays. 1 per cent. propoxur spray has also proved useful. Pyrethrins may be added to these sprays to act as a flushing agent. The fact that toxic chemicals are being used near to foodstuffs must be remembered, however, and every effort made to avoid contamination.

Other chemicals used for cockroach control have included sodium fluoride, boric acid and silica aerogels. The latter are very fine abrasive powders which remove the surface coating off the insect cuticle causing a water-loss and subsequent death by dehydration. One such aerogel is marketed under the name of ' Dri-Die '. Baits containing dichlorvos, propoxur or chlordecone (an organochlorine insecticide sometimes called kepone) are also popular methods of control.

Insecticide resistance is most widespread in the German cockroach and involves the organochlorines, organophosphates (diazinon, malathion and fenthion), the carbamate propoxur and even pyrethrins. Organochlorine resistance is also known in the Oriental cockroach and both organochlorine and organophosphate resistance in the American cockroach.

Mites

Surprisingly, the chlorinated hydrocarbon insecticides are relatively inefficient against the itch-mite (*Sarcoptes scabei*) and benzyl benzoate still remains one of the most successful sarcopticides.

The Trombiculid mites, *Leptotrombidium akamushi* and *L. diliensis* are vectors of scrub typhus in Asia and the South Pacific. Control measures involve area treatment with insecticides in the form of sprays or dusts, e.g. toxaphene or chlordane at 1–2 lb. per acre (454–907 gm./4,047 m^2) or lindane at 0·25–0·5 lb. per acre (113–227 gm./4,047 m^2), and personal protection with repellents. The latter are more effective when applied to the clothing than to the skin. The best appears to be benzyl benzoate which remains effective after the clothing has been washed. The true repellents, e.g. dimethyl and dibutyl phthalate and diethyltoluamide are only effective when fresh.

Biting Midges

The true biting midges (genera *Culicoides*, *Leptoconops*, *Styloconops*) are tiny blood-sucking Diptera capable of easily penetrating the common type of house-screening and mosquito and even sandfly netting. The residual spraying of houses has little effect on reducing their numbers; treatment of their breeding grounds, which are almost invariably extensive swampy areas, is commonly impracticable and always costly. Larval control has been carried out in the Americas by the application of DDT, BHC and dieldrin as dusts or pellets, usually dispersed from the air. Considerable relief from indoor biting can be obtained by painting the gauze screening of houses with 5 per cent. DDT or 8 per cent. malathion solution.

Black-flies

The larvae of the Simuliidae characteristically breed in rapid-flowing water. The adults, voracious feeders, do not enter or rest in houses to any extent and are therefore impossible to control by house-spraying. The larva is very susceptible to minute concentrations of residual insecticides, in particular DDT. Concentrations of the order of one part of DDT per ten million parts of water, maintained for a period of about half an hour, has effected the control of Simulium larvae in Canada, where the flies are a very great nuisance, and in Africa where two species are the vectors of onchocerciasis. The DDT in solution or emulsion is usually applied at the head of the water to be controlled, the quantity required being related to the rate of flow of water. Control has been achieved in this way as far as 100 miles downstream in Canada. Successful control has also been carried out by spraying along the affected watercourse from the air; at Kinshasa in Zaire, DDT was applied in this way at 20 mg./m^2 on several successive days and more or less eliminated the Simulium both as adults and as larvae.

DDT is said to be ineffective against pupae at larvicidal doses while gamma-BHC is said to be effective against larvae and pupae at 2 parts per ten million parts of water for fifteen minutes.

One apparent drawback to these larvicidal measures, especially where quantities of insecticide are applied at one point, is the detrimental effect on fish. When dispersed at 1 part in ten million, DDT is harmless but in parts of Kenya where dosages of 2 to 10 parts per million were used fish were killed.

Abate, the organophosphate of very low mammalian toxicity and of short persistence in the environment, is now being recommended for widespread and long-term use as a larvicide. Aerial spraying trials have achieved complete control over 50 km. of rivers by discharging a 20 per cent. emulsion concentrate to give a final dilution of 0·05 parts per million of insecticide.

Tsetse-flies

Tsetse-flies are confined to tropical Africa where 5 species are responsible for the transmission of human sleeping sickness and 10 for the transmission of disease of animals including domestic ones. Their presence over large areas of the continent has been largely responsible for restricted progress in agricultural development. They are not easy to control because of the resting habits of the adult flies in dense bush over extensive areas. However they have remained susceptible to insecticides and the distribution of these from the air or from ground equipment to preferred resting sites has led to their control and even complete eradication from sizeable tracts. Insecticides used have been DDT, BHC, dieldrin and endosulfan and only now are organophosphates, carbamates and pyrethroids being considered from fear of too

much pollution of the environment from the widespread use of organochlorines. Two spraying techniques have been developed. One aims at producing sufficient deposits of insecticides on the known resting sites of adult flies to have a residual effect. As well as ground equipment, helicopters have been used for this prupose. The other involves the aerial spraying of aerosols produced by injection of solutions of insecticide into the exhaust system of the aircraft or delivered through atomisers fitted to the wings. In Botswana, for example, endosulfan has been applied in this way from Piper fixed-wing aircraft 5 times at 21-day intervals at a total cost for fly eradication of U.S. $ 70–75 per km^2.

Scorpions

The application of gamma-BHC in houses at 50 mg. per sq. ft. (0·5 gm./m^2) has proved effective against scorpions in Brazil. In addition to the interior of houses, backyards and brick walls around the houses were sprayed. Stacks of wood and bricks were removed and the vacated places also treated; vacant lots were also given BHC. Five per cent. malathion, 2 per cent. chlordane and 1–2 per cent. carbaryl sprays have also been used successfully.

Ants

True ants often invade buildings and can be of considerable nuisance though never as destructive as termites. The only sure way of controlling these pests is by tracing them back to their source and destroying the nest (with boiling water or insecticides or general poison, e.g. carbon disulphide). The spraying of infected buildings with residual insecticides may considerably reduce them but is seldom completely satisfactory.

Poison baits have been used with some success in some instances. The ideal poison is one not too rapid in its effect so that contaminated worker ants have time to return to the nest and feed the poison to the queen and brood. By this means the poison is taken to the heart of the infestation. Such a poison is sodium fluoride which however must be put into a container to prevent accidental poisoning of children or domestic animals. A small tin or pill-box with holes punched in the sides to allow access of the ants is suitable. A liquid bait is apparently more effective than a solid one and a suitable formula is:—

Water	51	per cent. by weight
Sugar	42	per cent. by weight
Honey	6·2	per cent. by weight
Sodium fluoride ...	0·8	per cent. by weight

Weigh out sugar, honey and poison, add the water, heat and stir until a homogeneous syrup is obtained. Do not boil. The liquid should be kneaded into a mush with one to two parts of a solid ‘ carrier ’ (cake, minced meat or chopped liver). Prepared proprietary baits also exist.

Termites

Pentachlorophenol has been used for a considerable number of years as the basis of wood preservatives to prevent attack by termites and other wood-boring pests and seems to be efficient.

In the U.S.A. the insecticide chlordane is favoured for the control of termites. To protect buildings a trench is dug next to foundation walls 1 or 2 ft. (30 or 60 cm.) deep and 8 to 12 ins. (20 or 30 cm.) wide. A $\frac{1}{2}$ per cent. to 1 per cent. water emulsion chlordane spray is applied to the trench at the rate of 1 gallon per linear foot (4·5 litres per 30 cm.) and the soil for refilling the trench is also treated.

Repellents

It has been known for some considerable time that certain strong smelling oils, e.g. citronella, lavender, cedar-wood, eucalyptus, repel biting insects, though their period of effectiveness is not very great. During World War II dimethyl phthalate (D.M.P.) and dibutyl phthalate (D.B.P.) were brought into use for the protection of troops in jungles and other places where insect-biting nuisances were a major problem. Now a number of other chemicals are available and among these diethyltoluamide (D.E.T.) seems to show the most promise as an efficient and long-lasting repellent.

These repellents are usually applied to the skin of exposed parts of the body, e.g. hands and face, though additional protection is provided against such pests as scrub-typhus mites by impregnating the clothing at ankles, wrists and neck. The period of protection provided by any one of these repellents varies with the individual, the temperature, the amount of activity that would induce sweating, the amount of rubbing the treated surface receives and the avidity of the insects.

They should be used with caution, as they will damage such materials as plastic watch-glasses, some types of synthetic cloth (rayon, but not nylon), fingernail polish and articles that are painted or varnished. They will not damage cotton or wool.

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GLOSSARY OF INSECTICIDE NAMES

Common Names and Synonyms

(The currently used name is given first.)

Organochlorines

DDT=Gesarol
BHC=HCH
gamma-BHC=Gammexane=Lindane
DIELDRIN=Octalox
CHLORDANE=Octachlor
TOXAPHENE=Camphechlor
CHLORDECONE=Kepone
ENDOSULFAN=Thiodan

Organophosphates

MALATHION=Cythion
ABATE=Temephos=Difenphos=Biothion
RONNEL=Fenchlorphos=Nankor=Trolene=Korlan
FENITROTHION=Sumithion=Folithion
TRICHLORFON=Dipterex=Neguvon
NALED=Dibrom
DURSBAN=Chlorpyrifos
DIAZINON=Basudin=Exodin
DIMETHOATE=Rogor=Cygon=Perfekthion
FENTHION=Baytex=Lebaycid=Mercaptophos
GARDONA=Tetrachlorvinphos
COUMAPHOS=Asuntol=Co-Ral=Resitox
DICHLORVOS=DDVP=Nogos=Nuvan=Vapona
DIOXATHION=Delnav

Carbamates

CARBARYL=Sevin
MOBAM
PROPOXUR=Arprocarb=Baygon=Blattanex=Unden

Others

ROTENONE=Derris-Root=Tubatoxin=Cube
PYRETHRUM (Pyrethrins are the main insecticidal constituents of pyrethrum.)
ALLETHRIN=Pynamin
BIOALLETHRIN
RESMETHRIN=Chryson
BIORESMETHRIN
PERMETHRIN=NRDC 143

INFORMATION AND ADVISORY SERVICE

THE primary object of the Ross Institute is the prevention of disease in the tropics. In the course of working towards this end it has become apparent that the co-operation of industry is essential if rapid progress is to be made. Fortunately, this co-operation has never been lacking, for those responsible for directing tropical industry were quick to appreciate the immense value to them of healthy labour and have therefore been among the strongest supporters of the Ross Institute since its inception.

For this reason the Ross Institute has made it an important matter of policy to keep tropical industry informed of the progress of medical knowledge, and of the practical methods by which the greatest benefit may be obtained from its application. This series of bulletins, which have been specially written for non-medical people, is one of the means by which this information is made available; other publications are issued from time to time and a list of those now current will be found on the following page.

The Ross Institute invites all those whose work is connected with the tropics to refer to it on any matter concerned with health or welfare in tropical countries. The Director and his staff will answer as promptly and as fully as possible all inquiries and requests for advice.

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The Preservation of Personal Health in Warm Climates.
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Ross Institute Bulletins:—

(1) Insecticides. (*Revised*) *July*, 1976.

(2) Anti-Malarial Drugs. (*Reprinted*) *April*, 1975.

(3) (*Out of Print*)

(4) Tropical Ulcer. (*Revised*) *August*, 1973.

(5) The Housefly and its Control. (*Reprinted*) *August*, 1975.

(6) Schistosomiasis. (*Reprinted*) *May*, 1974.

(7) Malaria and its Control. (*Reprinted*) *May*, 1974.

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(9) The Inflammatory Diseases of the Bowel. (*Reprinted*) *August*, 1975.

(10) Small Water Supplies. (*Reprinted*) *April*, 1975.

(11) Anaemia in the Tropics. (*Reprinted*) *June*, 1974.

(12) Protein Calorie Nutrition in Children. (*Reprinted*) *June*, 1975.

These publications are revised from time to time and new and revised editions are issued as occasion warrants. They are available at printing cost plus postage on application to:—

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